



# NASA Subsonic Rotary Wing Project

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Multidisciplinary Analysis & Technology Development: Overview  
NASA Ames Research Center



2009 Fundamental Aeronautics Program Annual Meeting  
September 29-October 1, 2009

[www.nasa.gov](http://www.nasa.gov)

# Multidisciplinary Analysis and Technology Development (MDATD)

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**What** are the objectives of MDATD in the Subsonic Rotary Wing project?

- Integrate technologies and analyses to enable advanced rotorcraft
- Provide a “big picture” roadmap to guide Level 1 & 2 research

**How** will the MDATD objectives be met?

- Conduct assessments of advanced technology benefits
- Develop new or enhanced design tools
- Integrate Level 2 discipline technologies to develop and enable system-level analyses and demonstrations

# Elements of M DATD

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- Integrated Systems Technology Challenges
  - Integrated Aeromechanics/Propulsion System
  - Actively-Controlled, Efficient Rotorcraft
  - Quiet Cabin
  - NextGen Rotorcraft
- Design and Analysis
  - Tools
  - Technology Assessments

# **Integrated Aeromechanics/Propulsion System**

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## **Goal (2021)**

Reduce main rotor tip speed at high speed cruise ( $>100$  kts faster than current rotorcraft) by 50% compared to hover tip speeds while maintaining cruise aerodynamic efficiency. Develop and demonstrate technologies enabling variable-speed rotor concepts.

## **Why work on this?**

Reducing rotor rotation in high speed cruise will

- mitigate compressibility effects on advancing side for edgewise flying rotors
- improve propulsive efficiency for tiltrotors

# Actively-Controlled, Efficient Rotorcraft

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## **Goal (2019)**

Assess, experimentally and analytically, multiple active rotorcraft concepts for effectiveness in simultaneously increasing aerodynamic efficiency, controlling dynamic stall for high speed conditions, reducing vibration, and reducing noise.

## **Why work on this?**

Studies of large transport rotorcraft have concluded that active rotor control and active flow control will be necessary to achieve desired attributes of future rotorcraft.

# Quiet Cabin

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## **Goal (2017)**

Develop and demonstrate advanced structural concepts and design evaluation methods for interior noise and vibration reduction.

## **Why work on this?**

Presently, a predictive capability to correlate changes in drive system noise levels with expected changes in cabin noise levels does not exist. Predicting noise transmission through advanced structures and the resulting impact on interior noise (and consequently, passenger comfort) are required to provide guidance during aircraft design.

# NextGen Rotorcraft

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## **Goal (2021)**

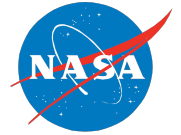
Foster, develop and demonstrate technologies that contribute to the commercial viability of large rotary wing transport systems in NextGen.

## **Why work on this?**

- Numerous studies suggest that large transport rotorcraft can reduce airspace congestion.
- Rotorcraft are critical public service aircraft and must be fully integrated in the NextGen

# Elements of MDATD

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- Integrated Systems Technology Challenges
  - Integrated Aeromechanics/Propulsion System
  - Actively-Controlled, Efficient Rotorcraft
  - Quiet Cabin
  - NextGen Rotorcraft
- Design and Analysis
  - Tools
    - NDARC
    - RotCFD
  - Technology Assessments



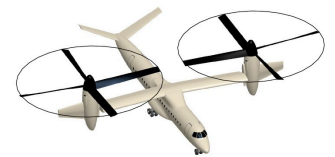
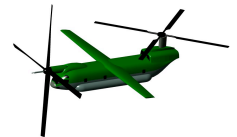
# New NASA Rotorcraft System Design and Analysis Tool

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- Tools available to government have out-of-date technology and software and limited capabilities
- Helicopter industry has proprietary tools
- Subsonic Rotary Wing Project requires a system analysis tool
  - For technology impact assessments
  - To define context for research and development
  - To support conceptual design efforts

***NDARC — NASA Design and Analysis of Rotorcraft***



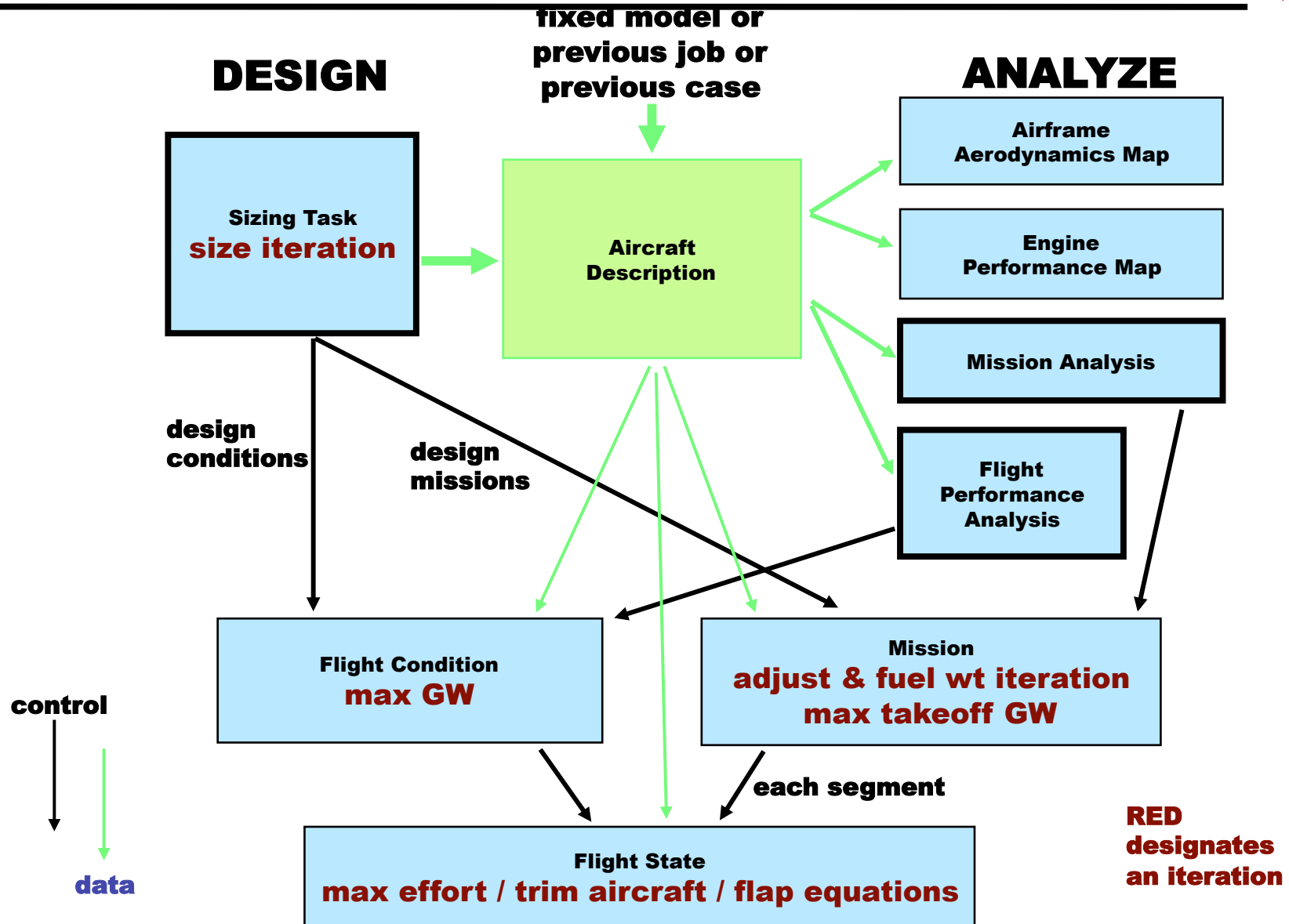
# Requirements Driving NDARC Development

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- Principal tasks
  - Design (size) rotorcraft to meet specified requirements, including vertical takeoff and landing (VTOL) operation
  - Analyze performance of aircraft for set of flight conditions and missions
- Multiple design requirements for sizing, from specific flight conditions and various missions
- Model a wide variety of rotorcraft configurations
- Expect software extensions and modifications routinely
- Complete and thorough documentation of theory and code
- Source code available to users

# NDARC Tasks



# NDARC Development Test Cases

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- Aircraft
  - UH-60A (helicopter)
  - CH-47D (tandem)
  - XH-59A (coaxial)
  - XV-15 (tiltrotor)
- Selected because for each aircraft have:
  - Flight performance data
  - Weight statement
  - Geometry
  - Comprehensive analysis model
- Validation and verification
  - Fixed aircraft (performance, weights, engine)
  - Then sized aircraft



# NDARC Status

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- Testing completed, initial releases distributed
  - Release 1.0 in May 2009, Release 1.1 in August 2009
  - Training in June 2009 (conducted by AFDD)
- Documentation
  - NASA TP 2009-215402 (Theory Manual) to be published
  - Input and Data Structures Manual
  - Wiki established (<http://wiki.nasa.gov/cm/wiki/?id=4875>)
- Code distribution: controlled by Software Release Authority at NASA Ames
  - In all cases subject to Software Usage Agreement (ARC-16265-1)
  - Approval obtained for General US Release + Worldwide Academic Release
- NDARC has been distributed (August 2009) to
  - NASA Ames Research Center, NASA Glenn Research Center
  - US Army AFDD, Naval Air System Command, AFDD JRPO
  - Iowa State University, Franklin D. Harris, Institute for Defense Analyses
  - Sikorsky Aircraft, Karem Aircraft
- Applications and further development
  - Including collaboration with other organizations

# NDARC Plans

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- Other configurations
  - Quad Tiltrotor, Autogyro, Compound
  - Tiltwing, Gyrodyne
- Other enhancements (in no particular order)
  - Reaction drive
  - Stopped rotors
  - Vectored wake/thrust of rotor
  - Turbojet/turbofan engine model, Piston engine model
  - Rotor trailing edge flap control, Flow control (fuselage, rotor)
  - Ducted fan aerodynamic loads
  - Compressible airframe aerodynamics
  - V-tail
  - VTO/STO and landing (with optimal control)
  - Aircraft mass distribution (cg and moments of inertia)
  - Noise
  - BEM theory, dynamic wake, airfoil tables
  - Improved models for rotor induced and profile power
  - Optimization

# NASA SBIR Phase 2 with Sukra Helitek, Inc.

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- **Objective**
  - Develop a CFD tool to efficiently analyze rotorcraft conceptual designs in external and internal flow
- **Approach**
  - Streamline CAD-to-grid process
  - Emphasize user-friendliness
  - Develop new flow solver: RotCFD

# Enable Efficient Transition from a Conceptual Design to a CFD Solution

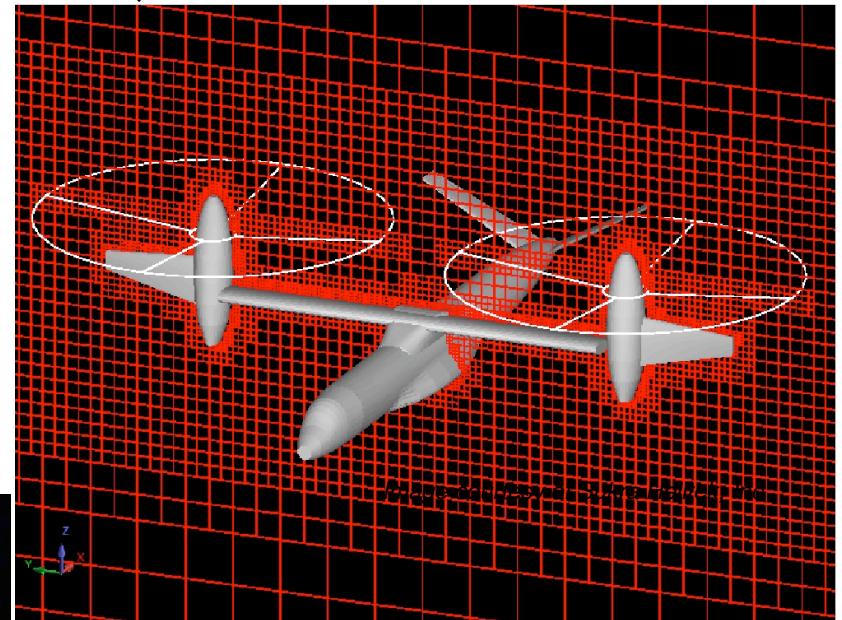
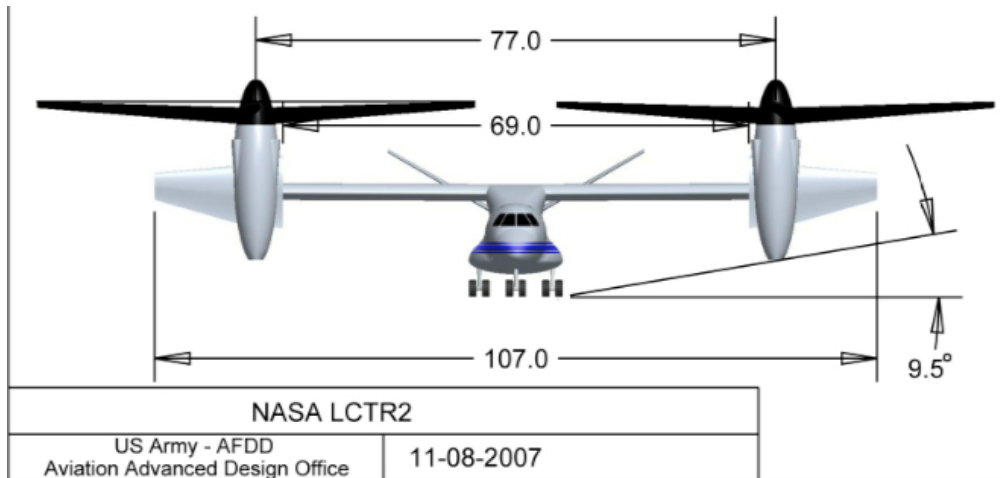
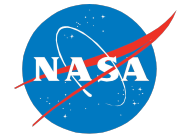


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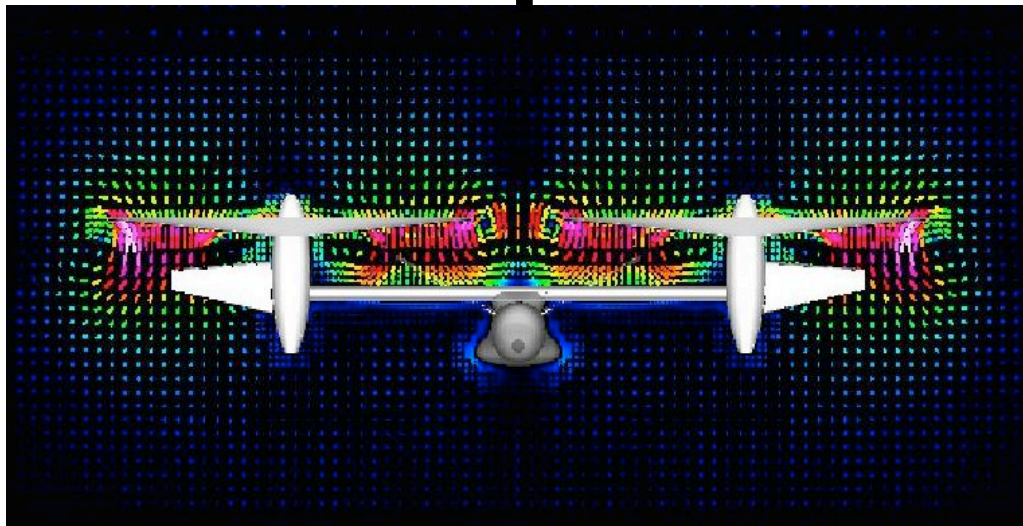


Image courtesy of Sukra Helitek, Inc



# RotCFD Overview

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- Capable of simulating flow over a complete rotorcraft configuration (with, without wind tunnel walls)
- User-friendly single interface with pre/post-processing tools to assist in design process:
  - CAD for geometry manipulation and parametric variation of geometry.
  - Grid generator with body-fitted grid (tetrahedral) and Cartesian unstructured grid away from the body.
  - Rotor performance, TRIM and body force calculations.
  - Flow visualization.

**Goal is to reduce design time and cost**

# Tool Comparison

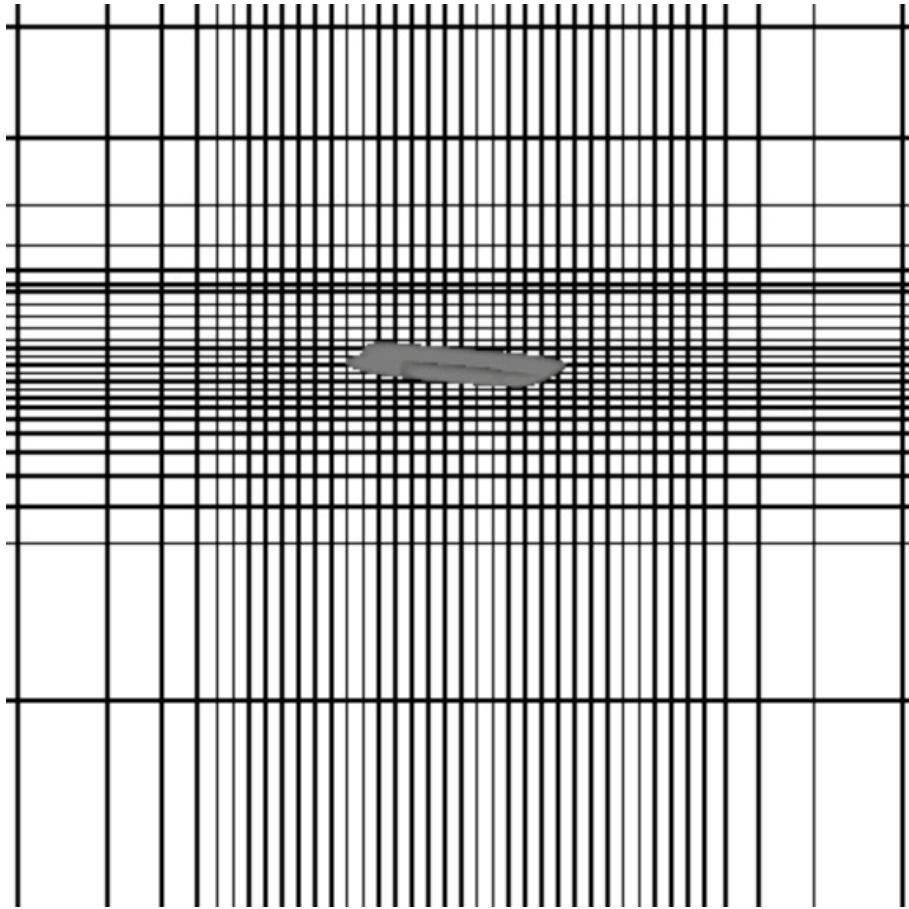
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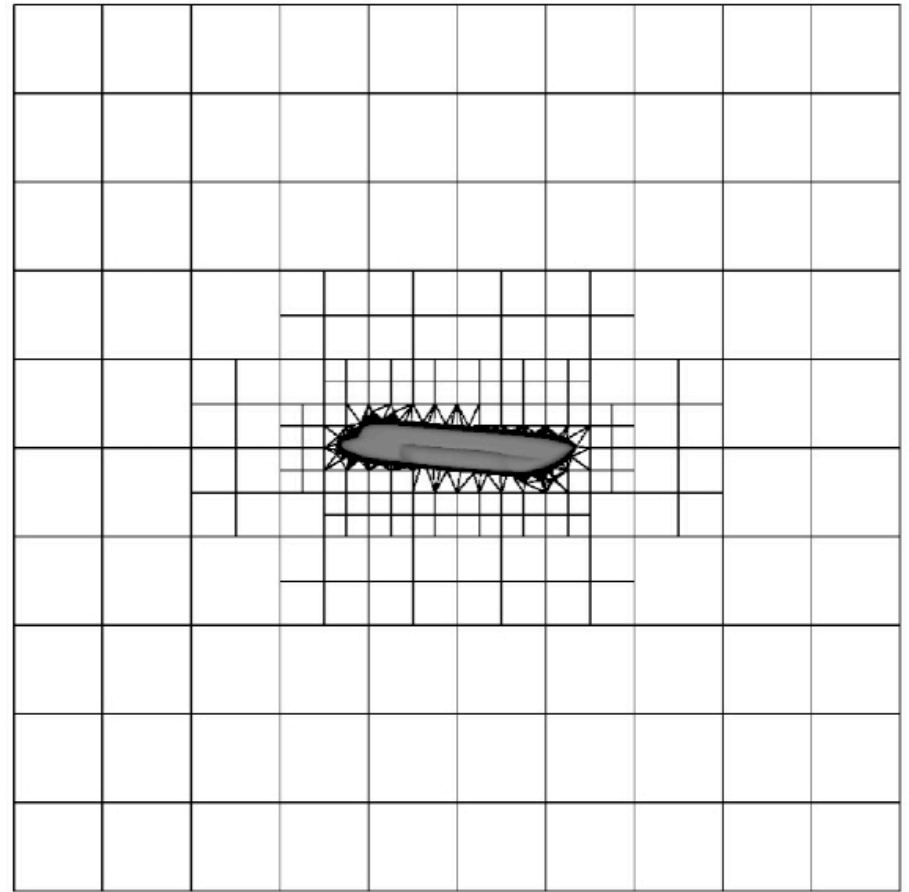
- RotCFD:
  - Hybrid grid
  - Resolution of geometry by body-fitted grid
  - CAD interface for geometry variation
- Rot3DC:
  - Cartesian grid
  - Geometry represented by blocked cells

# Grid Generation

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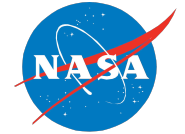


Rot3DC  
(Cartesian structured grid)

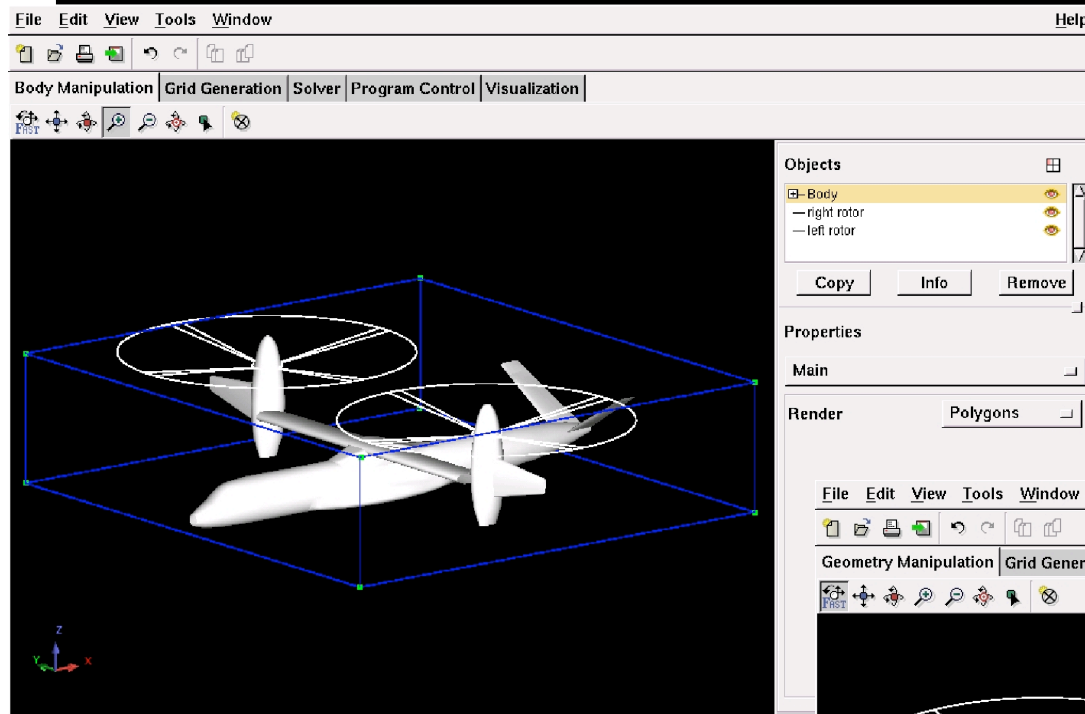


RotCFD  
(Hybrid grid)

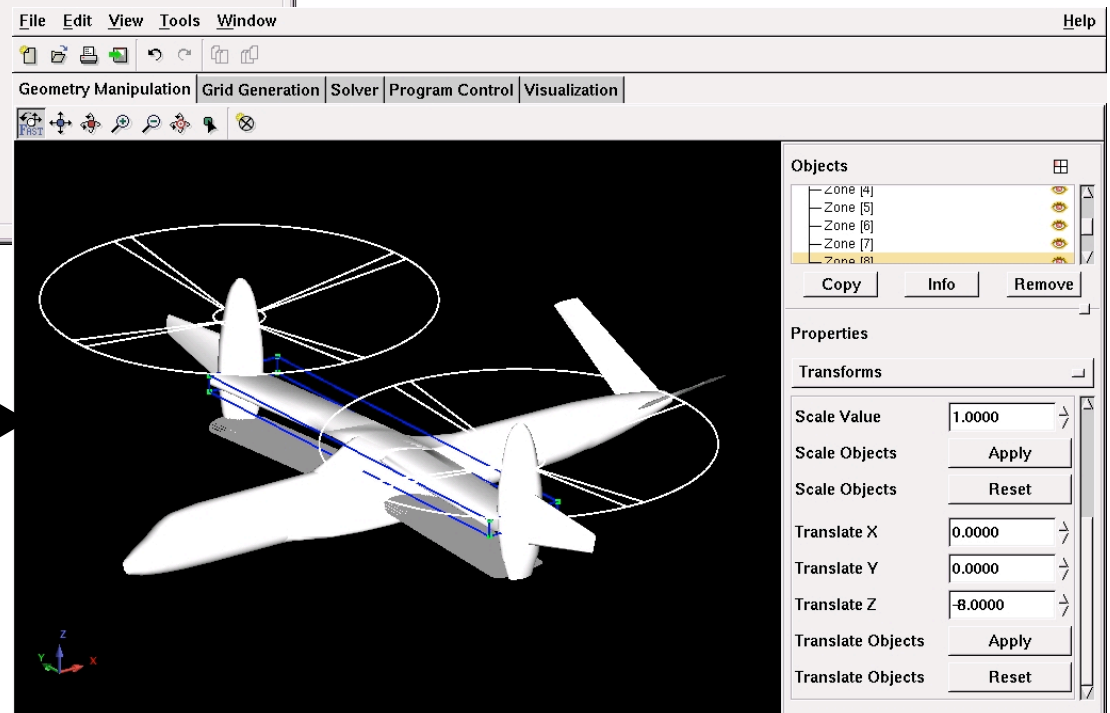
# RotCFD CAD Tool: Examples



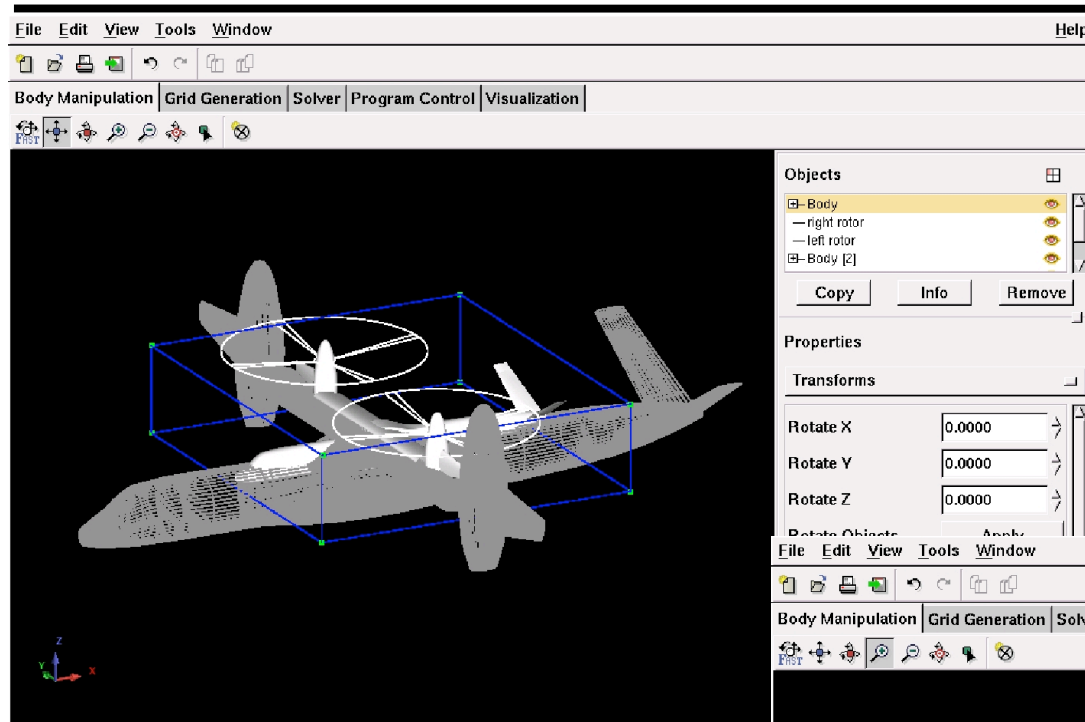
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Transformation from High  
Wing to Low Wing  
Configuration

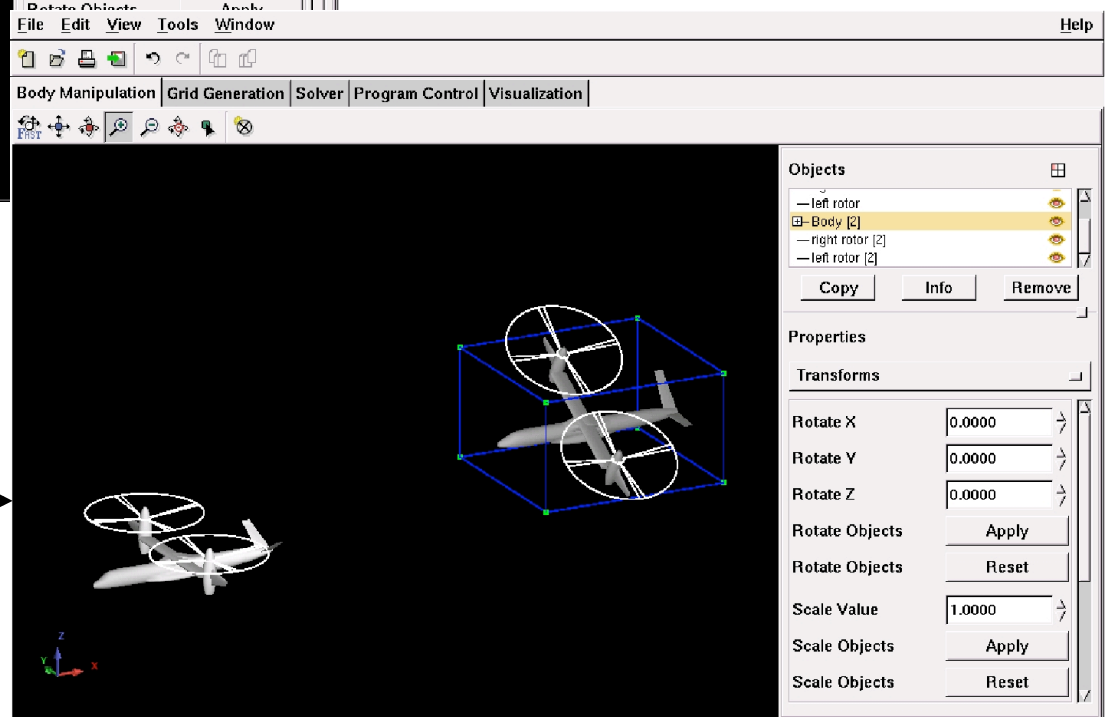


# RotCFD CAD Tool: Examples



← Scaling

Geometry duplication for formation flight and rotation of the rear aircraft



**Sukra Helitek, Inc.**

# Sukra Helitek, Inc.

## SBIR Phase 2: Status and Plans

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### Work completed

- Developed and implemented the solver algorithm for 2-D
- Tested the 2-D solver using a hybrid grid

### Planned Work

- Extension to 3-D and validation
- GUI and CAD development
- Flow visualization
- TRIM formulation
- Hybrid grid generation for complex geometries.
- Post-processing tools
- Integration of the tools into a single interface

# MDATD Accomplishments in FY09

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- Completed NDARC code development and documentation (Theory Manual to be published as a NASA TP)
- Initiated the study “Modeling High-Speed Civil Tiltrotor Transports in the Next Generation Airspace” via a GSA contract (Team: SAIC (prime), Bell Helicopter, Sensis, Optimal Synthesis)
- Initiated a study on variable speed engine/gearbox (Boeing)
- Publications
  - Orr, S. A. and Narducci, R. P.: Framework for Multidisciplinary Analysis, Design, and Optimization With High-Fidelity Analysis Tools. NASA/CR-2009-215563, February 2009.
  - Snyder, C. A. and Thurman, D. R.: Gas turbine characteristics for a Large Civil Tilt-Rotor (LCTR). American Helicopter Society 65th Annual Forum, Grapevine, TX, May 2009.
  - Wilkerson, J. B. and Smith, R.: Aircraft System Analysis of Technology Benefits to Civil Transport Rotorcraft. NASA/CR 2009-214594, June 2009.
  - Yamauchi, G. K. and Young, L. A.: A Status of NASA Rotorcraft Research. NASA/TP-2009-215369, September 2009.

